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ENERGY EFFICIENT AND COST SAVING PRACTICES IN DAIRY INDUSTRIES: A REVIEW

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ABSTRACT

The dairy industry handles a large amount of perishable liquid milk, which has to be processed or converted into value added products. This process consumes a great amount of fuel and electricity per year accounting to a higher production cost. There is a greater concern to minimize the use of energy to save cost and forward hands to conserve natural resources and control the global warming. There are a variety of opportunities available to reduce energy consumption and greenhouse gas emissions in a cost-effective manner. This paper discusses about various energy efficiency practices and energy-efficient technologies that can be implemented at the component, process, facility, and organizational levels to reduce the costs and to increase predictable earnings.

KEYWORDS: Energy, Cost, Specific Energy Consumption, Dairies & Energy Efficient Practices

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A Review Article

INTRODUCTION

In this developing and competitive era, every industry finds different means to reduce production cost without negatively affecting the yield or the quality of the finished goods. The importance of energy efficiency has been rapidly increasing in the last few years. This is mainly due to increased energy cost and depletion of natural resources (like coal, petrol, diesel etc). The unsustainable mode of energy usage and the effects of CO_2 emissions from fossil fuels are the other reasons of concern. The increase in energy cost may have a negative effect on predictable earnings. The dairy industry handling a large amount of milk uses energy in several forms such as steam, hot water, compressed air, chilled water and electricity. The dairies have to focus on both aspects of maintaining a high product quality and simultaneously reducing the production cost. These aspects can be met through investments in energy efficiency, which can include the purchase of energy-efficient technologies and the implementation of plant-wide energy efficiency practices. Energy-efficient technologies can often offer additional benefits, such as quality improvement, increased production, and increased process efficiency, all of which can lead to productivity gains. Energy efficient methods also reduce emission of green house gasses and other important air pollutants.

The higher standard of living and global economic development particularly in tiring cities have shown an increased demand for consumption of dairy products mainly specialty dairy products. Across the world increase in production there is an increase in energy demand for dairy processing. The dairy processing industry indulges in various processes associated with different milk products (such as heating, cooling, pumping etc) that require

energy for operating plant facility systems and processing equipment. This increasing demand for energy from dairy processing industry has been a major concern in terms of power availability and reliability as well as to environmental impact associated with greenhouse gas emissions and pollutants. According to the study conducted by Sevenster and De Jong, 2008 on European Union's dairy processing plants, it was estimated that the annual carbon dioxide (CO_2) greenhouse gas emissions from dairy processing plants are between 50 and 100g CO_2 per kg of milk. This would translate into total annual CO_2 emissions of tens of million metric tons associated with energy used in dairy processing plants in the world. Hence there is a very significant amount of CO_2 production form dairy processing plants which can cause many environmental consequences.

The energy efficient practices are important in many aspects of dairy processing like setting high level targets for company better performance, setting target and benchmarks for continuous improvement of individual plants justifying the purchase and installation of new equipment components. Through selecting and installing the best available technology, integrating various components of plant and operating the plant to the peak of its efficiency potential the savings potential in energy use associated with the dairy processing could be realized. In the current situation, there is limited information on energy efficiency for the milk processing and even the developing strategies or tools to improve the energy efficiency are also limited for dairy industry. There is also a gap between the developing strategies or tools and dairy industries, because not all dairies have the staff, resources, guides or tools to perform detailed assessment and identify opportunities for reducing energy use and greenhouse gas emission. The lack of knowledge and understanding of such opportunities by dairies form a barrier for improving energy efficiency in fluid-milk processing plants. Therefore, it is necessary to upgrade the information and to fill the existing knowledge gap to improve energy performance in the fluid-milk processing sector (xu and flapper, 2009).

ENERGY USAGE IN DAIRY INDUSTRY

In dairy industry different types of fresh milk products are produced which require different processes and treatments. The earlier stage of the fluid-milk processing involves milk reception and storing the raw milk at a low temperature (4–7˚C) to prevent it from perishing. The second step is filtration and standardization of solids content (mainly fat and protein), which will involve separation process. In addition, homogenization and pasteurization of the standardized milk is required prior to making of market milk. Different dairy products are produced by different processes such as ultra high treatment (UHT), Thermization (for liquid milk), centrifugation (for cream production), clarification (ghee clarifiers are used), churning (for butter production), concentration (for condensed milk production), drying (for milk powder production). For each of these steps daily cleaning-in-place (CIP) of the process and storage equipment is also required for hygiene reasons.

In dairy industry to conduct these processes, it spends billions of money on purchase of fuel and electricity. The Electricity is used throughout the dairy processing industry to drive process motors, fans, pumps and compressed air systems, as well as building lighting and HVAC systems. In addition to machine drives, one of the primary uses of electricity in the dairy processing industry is for process cooling, freezing, and cold storage. The largest share of fuel consumed by the dairy industry is used for direct process heating and steam generation via boiler systems. The remaining is used for miscellaneous process and building demands, such as HVAC systems. The fuels used include natural gas, coal, residual oil, and distillate oils (Brush, *et al.,* 2011).

SPECIFIC ENERGY CONSUMPTION

Specific energy consumption (SEC), sometimes also referred to as process energy intensity, has been adopted to benchmark energy intensity and to assess energy performance of the plants in a variety of industries (Ramirez *et al.,* 2006 and Worrell *et al.,* 2003). Specific energy consumption can be used as a metric to characterize energy usage in fluid-milk processing plants and processes. Specific energy consumption is defined as the energy use, primary energy or final energy (end use), divided by the production of fluid-milk products. The SEC provides energy intensity data for steam, refrigeration, electricity and direct fuel as well as total energy intensity used for any process. SEC can be applied to any specific process step within a fluid-milk processing plant (Equation 1), and can be used to calculate the overall SEC of a fluid-milk processing plant (Equation 2). Overall SEC is a measurement of the total production energy use of a plant normalized by final fluid- milk production.

$$\mathrm{SEC}_I = \frac{\mathrm{E_i}}{\mathrm{P_i}} \tag{1}$$

$$\mathrm{SEC}_i = \frac{\sum_{i=1}^{n} \mathrm{E_i}}{\mathrm{P}} \tag{2}$$

Where Ei is the actual energy usage of process step i, Pi is the production quantity for process step i, n is the number of process steps to be aggregated, and P is the total actual fluid-milk production.

By comparing the energy consumption value of a plant to benchmark SEC, the information can be developed which can be used to assess the energy efficiency potential of plant. A plant or a process with a lower SEC value indicates that it is more energy efficient. Table 1 represents the cost of energy for different processes in dairy industry.

Table 1: Process Wise Cost of Energy Consumption (BEE, 2010)

S. No	Process Name	% of Cost
1	Milk Processing	13
2	Refrigeration and Cold Storage	30
3	Packaging and Allied Services	12
4	CIP Washing and Cleaning	13
5	General Utility and Services	32

ENERGY EFFICIENCY PRACTICES

The dairy manufacturing industry has radically improved its energy efficiency over the last 20 years (in some cases by as much as 50%) through industry-wide upgrading of equipment and the closure of smaller, less efficient factories (Lunde *et al.,* 2003). The diary industry has put its hand forward to reduce the carbon emission and energy consumption of the industry as a whole, through energy efficiency practices and improvements. The most effective method of improving energy efficiency is to identify and implement cost saving energy efficiency measures and technologies at various levels of production. The SEC information can be used as a benchmarking tool and best practices can be recommended based upon SEC characterization and benchmarking (Xu *et al.*, 2009). The inefficient designs, processes, or systems within an individual plant can be identified by making process-specific comparisons between the energy used for each process at the plant and that used for the energy-efficiency target. Once the inefficient designs or processes are identified, energy-efficiency technologies and measures could be identified, recommended, and implemented to improve the energy efficiency of the processes.

REDUCING THE DEMAND FOR STEAM AND HOT WATER

Steam is the most significant end use of energy in the dairy industry and is primarily used in process heating applications such as pasteurization, cooking, and evaporation. Majority of steam systems use natural gas and coal as a boiler fuel, improving steam system efficiency can cut the excessive energy costs. In this paper some of the most significant opportunities available for improving steam system efficiency are discussed below

Boiler Efficiency

The efficient use of fuel depends upon the steam generator efficiency, which will operate most of time in dairy industry (Ganapathy, 1994). There are some basic considerations that should be followed for efficient boiler operation as listed below:

Reduce Excess Air

Air slightly in excess of the ideal stoichiometric fuel-to-air ratio is required for safety and to reduce emissions of nitrogen oxides, but approximately 15% excess air is generally adequate. But a higher use of excess air causes loss of heat in boiler, as large amount of heat is transferred to air rather than steam hence reducing the efficiency of boiler and payback period.

Flue Gas Monitoring

The monitoring of flue gases on a boiler makes sense ecologically as well as economically. The flue gas monitors help in measuring the amount of excess oxygen and /or carbon monoxide in the flue gases resulting from combustion. By using flue gas monitor, it is possible to detect even small air infiltration in flue gases. The air infiltration in exhaust gases means a higher CO or smoke content in the exhaust gas which is a sign of incomplete fuel burning. Using a combination of CO and oxygen readings, it is possible to optimize the fuel/air mixture for high flame temperature (and thus the best energy efficiency) and lower air pollutant emissions.

Regularly Record the Flue Gas Temperature

A good benchmark for efficient operation of boiler is measuring the stack gas temperature immediately after the boiler is serviced and cleaned. The stack gas temperature can then be regularly monitored and compared with the optimum reading at the same firing rate. It is estimated that there is a 1% efficiency loss with every 5˚C increase in stack temperature (Muller *et al.,* 2001). A major variation in stack gas temperature indicates that there has been a drop in efficiency and the air-to-fuel ratio needs to be adjusted, or the boiler tubes cleaned.

Properly Sized Boiler Systems

The boiler systems have to be designed to operate at the proper steam pressure. This can save energy by reducing stack temperature, reducing piping radiation losses, and reducing leaks in steam trap. It is important to ensure boilers are operating at their maximum possible design working pressures. Operating them at lower pressures will result in lower-quality steam and reduced overall efficiencies. If the system requires lower pressures, use pressure-reducing valves. The steam supply should be match the demand, if the steam production at the boiler house is too high compared to the plant's actual steam demand; the excess may need to be vented, resulting in unnecessary fuel wastage. The use of metering instrumentation (steam, water and fuel meters) will help match steam supply with demand.

Boiler Maintenance

A simple maintenance program to ensure that all components of a boiler are operating at peak performance can result in substantial savings. In the absence of a good maintenance system, burners and condensate return systems can wear or get out of adjustment. On average, the energy savings associated with improved boiler maintenance are estimated at 10%. Fouling on the fire side of boiler tubes or scaling on the water side of boilers should also be controlled. Scale acts as an insulator and inhibits heat transfer. A coating of scale 1 mm thick can result in a 5% increase in fuel consumption, and if the thickness is allowed to increase to 3 mm the fuel consumption can increase by 15% (MLA, 1997). On So proper cleaning of soot layer on fire side and preventing the build-up of scale by treating the boiler feed water can result in significant energy savings.

Flue Gas Heat Recovery

Heat recovery from flue gas is often the best opportunity for heat recovery in steam systems (CIPEC, 2001). Heat from flue gas can be used to preheat boiler feed water in an economizer. The improved economizers such as a condensing economizer can extract even more heat from the outgoing flue gas. A condensing economizer can improve steam system efficiency and heat recovery by up to 10% (DOE, 2007). A condensing economizer cools the flue gas below its dew point, which allows it to extract latent heat from the condensation of the flue gas vapor. Because the vapor is acidic, the condensing economizer must be resistant to corrosion, and any recovered water usually needs to be treated prior to reuse or discharge to the waste stream.

Condensate Return

The use of hot condensate return as feed in boilers can saves energy. It reduces the amount of feed water to be treated in RO plant, and reclaims water at up to 100°C (212°F) of sensible heat. A study of a Lithuanian dairy plant estimated that condensate return would reduce the boiler energy use by 8% (makaliunas and nagevicius, 1998).

Blow Down Steam Recovery

When water is blown from a high-pressure boiler tank, the pressure reduction often produces substantial amounts of steam. This steam is typically low grade, but can be used for space heating and feed water preheating. The recovery of blow down steam can save around 1% of boiler fuel use in small boilers (Galitsky *et al.,* 2005).

Direct Contact Water Heating.

In direct contact water heaters, water is sprayed downward through a vertical column filled with stainless steel packing rings. As cold water directly comes into direct contact with rising hot combustion gases, this water heating system is more efficient than traditional boilers. Hot water is collected in a storage tank while the combustion gases exit the system at near-ambient temperatures. Since water does not contact the burner flames, complete combustion occurs before the gases heat the water. Thus, water quality is maintained to a level that is appropriate for food processing operations (FIRE, 2005). Additionally, direct-contact water heaters can operate at atmospheric pressure, which avoids the safety hazards and insurance premiums that can come with pressurized boiler operation. One commercially-available direct-contact water heater by Kemco Systems, Inc., offers water heating efficiencies of up to 99.7%.

Steam Distribution System Energy Efficiency Measures

Steam and hot water distribution systems if not properly maintained can be major contributors to energy losses

within a dairy processing plant. Steam distribution systems should be designed for minimum heat losses and should be able to recover useful heat from the system wherever feasible. There are various measures for saving energy in industrial steam distribution systems, such as:

- Rectification of steam leaks
- Maintenance of steam traps
- Insulation of pipes
- Boiler condensate return system

REDUCING THE DEMAND FOR ELECTRICITY

Refrigeration

Refrigeration systems are a significant consumer of electrical energy in the dairy industry. The major applications of refrigeration systems in the industry are in the process cooling of milk and other dairy products, the cold bulk storage of raw and pasteurized milk, the freezing of ice cream, and the in generation of cold air for cold storage of almost all dairy products. The compressor is the heart of a refrigeration system and usually accounts for between 80% and 100% of the system's total energy consumption (Prasad *et al.,* 2005). The amount of energy used by a compressor is affected by:

Type of compressor: There are three main types of compressor used for refrigeration — reciprocating, rotary screw and scroll. It is important when selecting a compressor to choose a type best suited to the refrigeration duty and one that will enable the system's COP to be as high as possible.

Compressor load: The compressor's capacity should match the load. The oversized compressor operates at only partial load and the energy efficiency may be reduced. In some cases, even with a capacity control system an oversized compressor will still be inefficient as a result of frequent stopping and starting. The use of multiple compressors with a sequencing or capacity control system to match the load can help to improve efficiency. Ice bank tanks can be an effective way of meeting peak demands without the need for large compressor capacity.

Minimizing temperature difference: Compressors are most efficient when the condensing temperature (and therefore pressure) is as low as possible and the evaporating temperature (pressure) is as high as possible, while still meeting the refrigeration duties.

Increasing the evaporating temperature will increase the compressor efficiency, so the thermostats should not be set lower than necessary. Alternatively, the condensing temperature can be decreased by ensuring that the condenser is operating efficiently. Condensers should be sized correctly to maintain the optimum condensing temperature within the capabilities of the refrigeration system.

Reducing Load on Refrigeration Systems

The power consumption on refrigeration can increase from heat improper doorways in cold rooms. Automatically closing doors or an alarm system could be considered; and plastic strip curtains or swinging doors are useful at frequently opened entrances. Lights and fans also add to the heat load. Sensors and timers can be used to ensure that lights are used only when necessary.

Absorption Refrigeration

Absorption refrigeration system produces refrigeration effect from heat sources such as clean fossil fuels, incinerated garbage, biofuels, low-grade steam, hot water, exhaust gas or even solar energy, usually using a lithium bromide and water refrigerant (Broad Air Conditioning, 2004). The COP of absorption refrigeration, however, is relatively low compared with vapour compression refrigeration systems. The advantages of absorption systems are that they can utilize a waste heat source with lower greenhouse gas emissions compared to conventional vapour compression refrigeration systems.

Air Compressors

Compressed air is used extensively in dairy processing plants, mainly for the operation of valves, filling and packing machines, and for cleaning spray dryer bag filters. Typically, the efficiency of a compressed air system from compressed air generation to end use is only around 10% (CAC, 2002) and around 80% of electricity input is lost as waste heat. Compressed air systems are very energy-inefficient and therefore selecting and efficiently operating the correct type of compressor for the application can substantially reduce operating costs. Energy savings from compressed air system improvements can range from 20% to 50% of total system electricity consumption (Mc Kane *et al.,* 1999). Common energy efficiency measures for industrial compressed air systems are discussed below.

Compressed Air Leaks

Leaks in a compressed air system can contribute 20–50% of total air compression output (SEAV, 2002). Ultrasonic detectors can be used to check for leaks; the traditional method of using soapy water on pipe work is also effective.

Optimizing Air Pressure

Air pressure should be kept to the minimum required for the end use application. It is estimated that every 50 kPa increase in pressure increases energy use by 4% (SEDA, 2003).

Reducing Inlet Air Temperature

Up to 6% of a compressor’s power can be saved by using cooler air (SEAV, 2002). It is estimated that every 3°C drop in inlet air temperature decreases electricity consumption by 1% (SEDA, 2003).

CONCLUSIONS

The dairy processing industry spends huge amount on purchase of fuels and electricity, making energy a significant cost driver for the industry. Energy efficiency improvement is an important way to reduce these costs and to increase predictable earnings in the face of ongoing energy price volatility. The concern towards environment and increasing price of fuels has raised the alarm towards energy efficient measures. A focused and strategic energy management program will help to identify and implement energy efficiency measures and practices across the organization and ensure continuous improvement. This paper has summarized a number of energy-efficient technologies and practices that are proven, cost-effective, and available for implementation today.

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